Automatic Identification System
A General Discussion of Development, Application, and Implementation

By M. J. Lewandowski, Potomac Management Group, and
D. J. Pietraszewski, U. S. Coast Guard Research and Development Center
For USCG R&D Center Project 2410.5-Vessel Traffic Management Research

This introduces the Automatic Identification System (AIS) and discusses implementation issues. Class A international shipborne device standards are complete, and work continues on Class B and base station standards. This material is current as of June 2002. The paper addresses some Coast Guard specific issues but may interest other members of the Marine Transportation System (MTS) community.

AIS Background

An Automatic Identification System (AIS) has been under development since 1997 when the International Maritime Organization (IMO) drafted performance recommendations for a worldwide system. The IMO AIS recommendations state that AIS should improve safety "by assisting navigation of ships, protection of the environment, and operation of Vessel Traffic Services (VTS), by satisfying the following functional requirements: in a ship-to-ship mode for collision avoidance; as a means for littoral States to obtain information about a ship and its cargo; and as a VTS tool, i.e. ship-to-shore (traffic management)."[1]

In 1998, the Coast Guard Research and Development Center (R&DC) began participation "in the international development of AIS technology through the related work of organizations, including the International Electrotechnical Commission (IEC), International Telecommunications Union (ITU), National Marine Electronics Association (NMEA), etc.," and began to develop "tools, including a computer simulation, to assess the capability and capacity of a network of AIS devices."[2] Since then, R&DC emphasis has been on direct support for the international development and deployment of AIS technology. The R&DC is also active in the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) development of the definition and description of AIS base-stations and infrastructure. IALA has been the primary organization for sponsoring and coordinating AIS development.

Definition of AIS

IMO amendments to the SOLAS 74 Convention recommend, "AIS shall: provide automatically to appropriately equipped shore stations, other ships and aircraft information, including the ship's identity, type, position, course, speed, navigational status and other safety-related information; receive automatically such information from similarly fitted ships; monitor and track ships; and exchange data with shore-based facilities."[3] To accomplish this, an electronic device is used.

The AIS device consists of a Global Navigation Satellite System (GNSS) receiver, a microprocessor, and a VHF-FM transceiver (one transmitter/three receivers). The

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[1] International Maritime Organization, Sub-Committee on Safety of Navigation. Draft Recommendation on Performance Standards for an Universal Shipborne Automatic Identification System (AIS), NAV 43/15, Annex 21. London. 29 August 1997.
[2] U. S. Coast Guard. G-MOV/G-SCT/G-SCE memo 02000, Support for Universal AIS Standards. Sep 8, 1998.
[3] International Maritime Organization. Resolution MSC.99(73) - 2000 Amendments to the Safety of Life at Sea 1974 Convention, As Amended. London. 5 December 2000

microprocessor accepts data from a ship's sensors and packages this data with the vessel's identification and particulars into a digital signal. The signal is then automatically broadcast. When other broadcasts are received, the processor prepares the received data for display. Each device determines its own transmission schedule, and, in the presence of other stations, uses receipt of previous messages to ensure that stations do not transmit simultaneously. This *self-organizing* logic allows many AIS units to operate, without interfering with one another. Broadcasts are made on two VHF channels, subdivided into 2250 time slots each.

A minimum keyboard/display (three lines of alphanumeric characters) is an integral part of the AIS device. It is primarily intended for control of the device. A standard marine interface (IEC 61162-1/ NMEA 0183) allows a variety of display methods. AIS information could be presented on an Electronic Charting System (ECS), Electronic Chart Display and Information System (ECDIS), radar display, or computer.

As provided in the International Telecommunications Union-Radio (ITU-R) Recommendation M.1371-1, there may be various types of AIS stations:[4]

- **Class A** – Shipborne mobile device meeting IMO SOLAS carriage requirements
- **Class B** – Shipborne mobile device, interoperable with Class A units but not in full accord with IMO SOLAS carriage requirements
- **Search and Rescue Aircraft** – aircraft mobile device supporting surface search operations
- **Aids to Navigation** – augments visual aids to navigation
- **Base [Shore] Station** – Shore-based device supporting VTS and surveillance services

Class A AIS

Only the Class A AIS is fully defined as to what it is, and what it must do. The performance standards adopted in 1998 include *functionality*, *capability*, and *information* requirements.[5]

Functionality applies to multi-mode operation. In addition to continuous operation on its own, the device can be automatically switched to an "assigned" mode by commands from a base station. The device will also respond to interrogations or "polls" from other devices.[6]

Capability includes operation in the VHF marine band, support of long range reporting systems, high-resolution electronic position-fixing, automatic input of navigation and maneuvering information, manual data input and retrieval, error checking and built-in test equipment.[7]

The performance standard states:

> "The AIS should be capable of providing information automatically and continuously...; receiving and processing information from other sources...; responding to high priority and safety related calls with a minimum of delay; and

[4] International Telecommunications Union Sector for Radiocommunications, Recommendation M.1371-1, Technical Characteristics for a Universal Shipborne Automatic Identification System Using Time Division Multiple Access in the Maritime Mobile Band. Geneva. August 2001.

[5] International Maritime Organization. Report of the Maritime Safety Committee on its Sixty-Ninth Session. Recommendation on Performance Standards for an Universal Shipborne Automatic Identification System (AIS), MSC 69/22/Add. 1 Annex 12, p 14-16. London. 1 June 1998.

[6] Ibid.

[7] Ibid.

providing positional and maneuvering information at a data rate adequate to facilitate accurate tracking by a competent authority and other ships."[8]

For instance, the reporting interval for a vessel on a straight course at a speed less than 14 knots is once every 10 seconds, while a vessel moving at over 23 knots reports once every 2 seconds.

Information includes static, dynamic, and voyage related elements. Static information is manually entered on installation and seldom changed. Dynamic information is automatically entered from ship sensors, while voyage related information is manually entered and updated as appropriate. The following table is adapted from the IMO AIS performance standards.

CLASS A AIS INFORMATION[9]

STATIC	DYNAMIC	VOYAGE RELATED
IMO Number	Vessel's Position*	Vessel's Draft
Call Sign & Name	Time (in UTC)	Hazardous Cargo (type)**
Length and Beam	Course over Ground (COG)	Destination and ETA#
Vessel type	Speed over Ground (SOG)	
Location of position fixing antenna	Heading	
	Navigational Status##	
	Rate of Turn	

* With accuracy indication and integrity status
\# At master's discretion
**As required by competent authority
\## e.g. anchored, not under command, fishing; manual input.

In December 2000, IMO member states adopted amendments to the SOLAS conventions that included AIS carriage requirements. These apply to all ships of 300 gross tons or more on international voyages, cargo ships of 500 gross tons or more not on international voyages, and all passenger ships. This has immediate effect for vessels built on or after 1 July 2002. For vessels built before 1 July 2002, the implementation timeline is a phased approach to be completed by 2008 as described below:

Ships engaged on international voyages:
1. Passenger ships, not later than 1 July 2003;
2. Tankers, not later than the first survey for safety equipment on or after 1 July 2003;
3. Ships other than passenger ships and tankers
   a. 50,000 gross tons or more, not later than 1 July 2004;
   b. 10,000 gross tons or more but less than 50,000 gross tons, not later than 1 July 2005;
   c. 3,000 gross tons or more but less than 10,000 gross tons, not later than 1 July 2006.
   d. 300 gross tons or more but less than 3,000 gross tons, not later than 1 July 2007; and

Ships not engaged on international voyages, not later than 1 July 2008.[10]

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[8] Ibid.
[9] Ibid. p 15
[10] IMO. Resolution MSC.99(73). MSC 73/21/Add. 2 ANNEX 7, Page 137

At a special IMO security working group meeting in February 2002, the United States proposed that "dates in [the SOLAS regulations] be amended to require the installation of AIS not later than 1 July 2004."[11] This is now under review.

Class B AIS

The majority of the world's vessels are not subject to SOLAS, so allowance is made for a shipborne mobile AIS device, not necessarily in full accord with IMO carriage requirements. Work is underway at IEC to draft a Class B equipment recommendation. The goal is an adopted International Standard (IEC 62287) by late 2003. It will include minimum operating characteristics and test requirements for Class B AIS certification. Generally, Class B AIS will have reporting rates less than the Class A AIS, and will provide less information (i.e. no rate of turn, draft, navigational status, destination and ETA, etc.).

Search and Rescue Aircraft

The IALA Guidelines are quite straightforward about AIS use in maritime search and rescue (SAR) and as an aid to navigation (ATON). Search and Rescue (SAR) aircraft may be fitted with AIS. The concept behind SAR aircraft AIS is to allow all participants in a SAR activity to have a clear picture of resource position and availability. Development in this area has not yet started.

Aids to Navigation

This is a potentially large use for AIS. Possible applications include real-time weather and oceanographic information, accurate actual position of a floating aid to navigation (and correlating whether it is "on station"), and performance monitoring. An Aid to Navigation may also be equipped as an AIS base station used for longer-range detection of AIS-equipped vessels. It could receive and re-transmit AIS information to another location for maritime domain awareness or vessel traffic management purposes.

AIS Base [Shore] Station

AIS base stations will play a major role in vessel traffic management and littoral state monitoring applications. They will serve as information bridges between the mobile AIS stations and land based infrastructures. Base stations will be able to perform a variety of optional functions. They may be used for managing the AIS radio channels where use of alternate channels may be necessary, or to interrogate AIS stations. The base station may have the capability to act as a "repeater" – to rebroadcast AIS information received from other stations. It could also be used to broadcast navigation safety information.

Shore station design and operation is currently being investigated by the IALA AIS Committee. The progress of the current work can be found in the "IALA Guidelines on AIS[12]" available on

[11] International Maritime Organization, Maritime Safety Committee. 75th Session, Agenda item 17. London. 15 January 2002.
[12] International Association of Aids to Navigation and Lighthouse Authorities (IALA). Guidelines on Universal Shipborne Automatic Identification System (AIS).Version 1.0. St Germain En Laye – France. December, 2001.

the IALA web site. In addition to the shore station, the Guidelines provide a comprehensive description of AIS, and the different types of potential uses.

AIS Information Use – Vessel collision avoidance

The primary emphasis of AIS is collision avoidance. The International Regulations for Prevention of Collisions at Sea (COLREGS) require "use of all available means appropriate"[13] for collision avoidance. AIS will be one of those means. AIS may improve situational awareness. In comparison to radar and automatic radar plotting aids ("own ship" information), AIS information is provided directly from the "other" ship's sensors (GNSS position, SOG, COG, heading, rate of turn, etc.), with each vessel's name and call sign.

In its guidelines for operational use, IMO cautions "not all ships carry AIS," and even if AIS carriage is mandatory, it "might, under certain circumstances, be switched off on the master's professional judgment."[14] The guidelines continue to caution "that information provided by AIS may not be giving a complete or correct 'picture' of shipping traffic in [a user's] vicinity."[15]

Since AIS is a new tool, use and familiarity may provide additional operational insight. The IMO Assembly specifically "requests the Maritime Safety Committee to keep the Guidelines under review and amend them as appropriate."[16] IMO also recognizes "the potential of AIS as an ***anti-collision*** device"[17] and goes on to suggest that "AIS may be recommended as such a device in due time."[18] As with any navigational aid or device, the prudent mariner uses all means at their disposal for safe navigation and does not rely solely on one piece of equipment or system.

One of many concerns about AIS information is its shipboard presentation. Work to determine mariner requirements continues, in particular with respect to human interface needs. The Coast Guard R&DC began an "AIS-like" demonstration project on San Francisco Bay in 1997[19]. Participants emphasized the need to use displays that limit "clutter" with a minimum amount of text. Operators preferred showing vessels as icons on a chart-like display. They desired the ability to use a display cursor to get more detailed information when needed. Another test was conducted in Canada in 1999 to provide operational experience with AIS and assess ways of integrating it with ECDIS.[20] Again, mariners emphasized the need to minimize on-screen clutter, and to show additional information only on demand. In another user-based test, experienced masters said that one of the most important benefits of AIS was the ability to identify a vessel by name, so as to make subsequent VHF communications direct[21] (rather than calling to "vessel off my port bow…").

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[13] International Maritime Organization. Convention of the International Regulations for the Prevention of Collisions at Sea (COLREGS). London. 1972.
[14] IMO. Guidelines for the Onboard Operational use of Shipborne AIS pp. 6-9
[15] Ibid.
[16] Ibid. p. 1
[17] Ibid. p. 9
[18] Ibid.
[19] Edwards, Michael; Pietraszewski, David. Automatic Identification System (AIS) User Requirements. (CG-D-03-01). USCG Research and Development Center. Groton, CT. December 2000.
[20] Pot, Fred W. AIS Test, British Columbia. Marine Management Consulting. Seatle, WA. 1999
[21] Braden, Rickard; Hedman, Torbjorn; Lagerstrom, Jonas; Malmkvist, Fredrik; Prytrz, Anna. A Psycho-Social Evaluation of BAFEGIS. Evaluation of AIS and ECDIS in the Baltic Ferry Guidance and Information System (BAFEGIS) Project. Kalmar Maritime Academy. Sweden. 1999

IALA recommends "AIS target symbols" as shown below.[22] These symbols resulted from an effort to differentiate AIS information from existing ECDIS and ARPA representations.

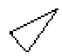
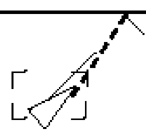
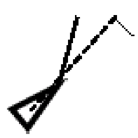
AIS target	Symbol	Description of symbol
AIS target (sleeping)		An isosceles, acute-angled triangle should be used with its centroid representing the target's reference position. The most acute apex of the triangle should be aligned with the heading of the target, or with its COG, if heading information is not available. The symbol of the sleeping target may be smaller than that of the activated target.
Activated AIS target		An isosceles, acute-angled triangle should be used with its centroid representing the target's reference position. The most acute apex of the triangle should be aligned with the heading of the target, or with its COG, if heading information is not available. The COG/SOG vector should be displayed as dashed line starting at the centroid of the triangle The heading should be displayed as solid line of fixed length starting at the apex of the triangle A flag on the heading indicates a turn and its direction in order to detect a target manoeuvre without delay A path predictor may also be provided
Selected target		A square indicated by its corners should be drawn around the target symbol.
Dangerous target		A bold line clearly distinguishable from the standard lines should be used to draw the symbol. The size of the symbol may be increased. The target should be displayed with: vector, heading and rate of turn indication. The symbol should flash until acknowledged. The triangle should be red on colour displays.
Lost target		A prominent solid line across the symbol, perpendicular to the last orientation of the symbol should be used. The symbol should flash until acknowledged. The target should be displayed without vector, heading and rate of turn indication.

Table 4-1: Recommended AIS Target Symbols

AIS Information Use – Shore Based AIS

IMO specifically included littoral state monitoring and vessel traffic management in AIS functionality.[23] Shore-based AIS information flow will offer a wide range of possibilities and

[22] IALA, Guidelines on Universal AIS. p. 63.

complementary uses. It also presents an organizational challenge to maximize AIS benefits. AIS infrastructure designers must look at two issues: the location of AIS base-stations (planned VHF Data Link coverage) and the information transfer architecture (AIS Network) for the "application-oriented processes of exchanging AIS-related information."[24] Together, these are considered a "high-level" system. A sound AIS "high-level" system infrastructure may be one of the most important elements in an Intelligent Waterways System.

A plan for effective shore-based use of AIS requires attention to quality reception capabilities as well as current and future base-station transmission coverage requirements. Vessel traffic management and littoral state monitoring may well represent the minimum shore-based AIS capability exploited by the USCG. The challenge is to link this newfound capability to broader Marine Transportation System needs - including basic marine information transfer. From the outset, the design of a high-level system should allow for growth, both in the amount of information transferred throughout a network, and in the ability of the VHF data-link to function as an active piece of an Intelligent Waterways System. Offshore, coastal, harbor, and inland AIS uses and requirements have many similarities, but some shore-based functions may conflict. For example "broadcast notices to mariners" scheduling may conflict with local traffic management.

IMO and IALA stress AIS base stations be managed and operated by the appropriate "competent authority." This legalistic term, "competent authority," is not commonly used in the United States. It is mentioned over forty times in the IALA Guidelines concerning establishment of AIS functionality, and maintenance of order and discipline on the VHF Data Link within a particular area. In a proposal "establishing a Community monitoring, control and information system for maritime traffic," the Council of the European Union defines "competent authorities" as "the authorities and organizations authorized by Member States to receive and pass on information reported pursuant to [the] Directive."[25] Another international definition considers "competent national authority" as the body "within whose competence the matter lies, for the enactment of legislation or other action."[26] Ostensibly, for AIS in the United States, the Coast Guard would most likely be viewed as a "competent authority." The Coast Guard is the United States representative to IMO and IALA, and has responsibility for marine safety, aids to navigation, and vessel traffic management. It's also reasonable to consider that other agencies might be "competent authority" in some geographically specific areas.

On the Great Lakes, vessel traffic management is conducted by both the United States and Canada. The St. Lawrence Seaway AIS is being developed so as to be "compatible" with standards under development with the St. Mary's River VTS. For most of the U.S. Territorial waters, we can expect the Coast Guard to act as the "competent authority," but in certain cases (Cape Cod Canal, Chesapeake and Delaware Canal, and Western Rivers), the U. S. Army Corps of Engineers might be the more appropriate "competent authority."

The St. Lawrence Seaway System is constructing a network of seventeen (17) AIS base stations covering the St. Lawrence River (Montreal to Lake Ontario), Lake Ontario, the Welland Canal,

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[23] IMO. (1997) Draft Recommendation on Performance Standards for an Universal Shipborne AIS.
[24] IALA, Guidelines on Universal AIS. p 86.
[25] Commission of the European Communities. Amended Proposal for a Directive of the European Parliament and of the Council Establishing a Community Monitoring, Control and Information system for Maritime Traffic. Brussels. 12 October 2001
[26] International Labor Organization. "Submission to the Competent National Authorities." http://ilo.org/public/english/standards/norm/howused/submit.htm

and Eastern Lake Erie. Seaway specific AIS messaging provides vessel lockage schedule, lockage order, meteorological conditions, water levels and flow rates, and Seaway status and advisory text messages. System goals include efficient traffic management, timely scheduling of inspections, dispatch of pilots, better scheduling of lockages and tie-ups, and faster response times to accidents or incidents. AIS will be mandatory on all commercial vessels transiting through the Seaway traffic sectors from St. Lambert to mid-Lake Erie in April 2003.[27]

On leaving the Welland Canal and transiting Lake Erie, an upbound seagoing vessel enroute western Lake Superior then will encounter Sarnia VTS for navigation on the Detroit River, Lake St. Clair, and St. Clair River, and after transit of Lake Huron, VTS Sault Ste. Marie. At this time, the degree of commonality and amount of information transfer among traffic management centers has not been determined, however, the Seaway messaging formats and specifications have been "harmonized" with planned, Coast Guard Ports and Waterways Safety System (PAWSS) AIS messages.[28]

In Europe, Sweden probably has the most extensive AIS network. This is a system of thirty-five (35) shore based AIS stations designed to provide full coverage of Swedish territorial waters. Operated on joint-venture basis between the Swedish Maritime Directorate and Swedish Military, the system provides coverage and information to VTS stations, and to the Maritime Rescue Coordination Center (MRCC) at Gothenburg. With this capability, SAR coordinators will be able to monitor and manage resources for SAR operations.

Functional Management and Planning for a High-Level System – VHF Data-Link and Shore AIS Network

Knowledge of AIS limitations, understanding near-term operational needs, and realistic appraisal of future operational requirements are appropriate for developing a high-level system. Full definition and functionality of an AIS base station is under development.[29] AIS shore station operation will include both reception of mobile AIS signals and transmitting messages. Three important AIS constraints are: (1) coverage is location dependent (VHF signals are effective for limited distance), (2) AIS is time dependent (there are only a certain number of "slots" available), and (3) all AIS stations must operate on two AIS channels. The critical issues facing the Marine Transportation System (MTS) and desired state of the MTS in 2020 as described in the Department of Transportation's Report to Congress[30] contain many operational needs and requirements. Also, adjacent countries may have different plans for shore-based AIS use in their waters.

Two examples of functional management issues are "channel management" and fixed time slot allocation. Should a competent authority want AIS messages on frequencies other than the two universal channels (AIS1 and AIS2), it would automatically direct a mobile AIS to change to those frequencies when within specific geographic areas. This might be done in areas where the two universal channels are "not available" (used for other purposes), or where traffic

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[27] AIS Project. Great Lakes St. Lawrence Seaway System. http://www.greatlakes-seaway.com/en/navigation/ais_project.html
[28] U. S. Department of Transportation, John A. Volpe Transportation Systems Center. St. Lawrence Seaway AIS Data Messaging Formats and Specifications, Revision 4.0. Cambridge, MA. April 25, 2002.
[29] IALA, Guidelines on Universal AIS. pp 136-140.
[30] U. S. Department of Transportation (DOT), An Assessment of the U. S. Marine Transportation System, A Report To Congress, September 1999. pp viii-xiii.

management schemes dictate. The time slot allocation issue is fundamental to base station operations. As AIS base station messaging requires fixed time slots, one or more competent authorities might desire different messages be transmitted. Depending on the location, and prospective number of AIS mobile units in the area, the competent authorities must cooperate to ensure that base station messaging does not eliminate available time slots to the extent that mobile AIS stations cannot effectively perform their primary function of vessel to vessel collision avoidance. A combination of interagency or intergovernmental agreements among competent authorities will be necessary to maintain order and discipline on the VHF Data Link within a particular area.

By nature of the geography, European countries are forced to confront AIS issues together. Finland and Sweden have successfully tested "interconnecting the AIS-systems of both countries."[31] The multilateral Helsinki Committee recently decided that AIS data would be shared between countries on the Baltic Sea. This effort may include a concept called "AIS roaming" which might enable vessels and competent authorities to exchange vessel reports and safety messages regardless of vessel location[32] much the same way the European mobile phone system operates.

A plan for a U.S. AIS infrastructure must include political and geographic concerns of possible shore based AIS authorities who have different waterways management goals. The interaction of the shore based AIS infrastructure and AIS messages on the VHF Data Link (VDL) must be guided by a common "concept of operations." The integrity of the VDL can be compromised by mismanagement of the AIS shore network. The scope and design of an AIS high-level system infrastructure must be based on a logical review and justification of potential operational requirements. Adjacent, sovereign governments' needs for vessel traffic management schemes or vessel exclusion zones may also play into the design of both the VHF data link and the AIS network. In comparison, the St. Lawrence Seaway AIS represents a simple model that addresses only a specialized broadcast system in a constrained geographic area.

A likely AIS network implementation scenario could include a phased-in approach. AIS based VTS systems are being established with their own internal networking. At a later point in time, coastal monitoring devices or non-government sites could be linked with the nearest VTS. In the future, a central site could also join the network. The U.S. Coast Guard will be positioned to lead development of a national AIS implementation plan.

Information Transfer

A high-level AIS scheme involves the continuous flow of large amounts of data. The "best" way to accomplish efficient information transfer is its own exercise in planning. Information needs will drive the network design.

There are many potential uses for AIS-derived information. A partial list of Coast Guard internal uses and other MTS stakeholder uses follows. AIS has the potential to drastically reduce the amount of radio and telephone voice communications among the MTS community. Today, voice

[31] Backstrom, R., Koivisto, M., Kuokkanen, L., Jokinen, J. "An Intelligent Shared Data Network for AIS and Remote Controlled VTS VHF." As presented at the XVth IALA Conference-March 2002, Session 5, Future Developments and New Technologies. Australia. p. 83.
[32] Ibid. p 96.

communications are used to obtain vessel location, ETA, etc., directly from the vessel or by using calls to shore-side entities for the same information. AIS is an alternative to the current practices.

LIST OF COAST GUARD MISSION AREAS AND POTENTIAL USE OF AIS INFORMATION

Coast Guard Mission Area	Use of AIS information
Maritime Domain Awareness	Monitor vessel movement into Customs Waters, Contiguous Zone, Territorial Sea, Internal Waters and vessel location at harbor facilities.
Vessel Traffic Management	Monitor vessel movement as per traffic routing/separation schemes, and vessel traffic control regulations. Monitor anchorage and safety zone compliance.
Port Security	Positive identification of vessels. Monitor security zone compliance.
Port Safety	Identification of IMDG cargo. Identification of non-CG vessel resources available for port safety assistance/emergency towing.
Search and Rescue	Identification of non-CG vessel resources available for SAR assistance. Position reference for distress notification verification.
Ice Breaking	Identify vessels and icebreaking resources for near-term planning and convoy operations
Environmental Protection/Response	Schedule compliance boardings, identify all resources available for response
Marine Resource Protection	Monitor compliance with vessel exclusion zones
Short Range Aids to Navigation	Monitoring SRA status and whether on station (when developed)
Own Resource Tracking	Monitor CG vessel movements (possible)

LIST OF NON-COAST GUARD MTS STAKEHOLDERS AND POTENTIAL USE OF AIS INFORMATION

Other MTS Stakeholders	Use of AIS information
Other Government Agencies	Monitor own vessel movements, other vessel traffic in areas of responsibility (locks, waterways)
Pilot dispatch	Monitor vessel movement, accurately schedule pilot boat meeting
Harbor tug dispatch	Monitor vessel arrival, accurately schedule tug arrival w/correct vessel, track own resources
Escort tug dispatch	Monitor vessel movement, know location of vessel in need of assistance
Steamship Agent	Monitor vessel movement, accurately schedule linehandlers, labor, government officials
Berth/Terminal Operator	Monitor vessel movement, ensure berth is clear
Vessel Fleet Operator	Track own vessel fleet
Harbormaster	Identify speed/wake regulation violators
Launch Operator	Know location of each vessel in anchorage to efficiently plan launch schedule, deliveries
Port Authority	Locate all vessels in area of responsibility
Ferryboat Operator	Determine traffic patterns in advance of pending ferry movement
Bunker supplier/ship chandler	Ensure vessel is anchored or at berth before arriving with delivery
State Regulatory Agency	Schedule compliance boardings and examinations, monitor activities within regulated areas
Highway Department	Early coordination for bridge openings or delays
Railroad	Coordination for bridge openings/delays, scheduling of train movements
Marine Exchange	Monitor all harbor activity
Academia	Monitor activities for studies and analyses

To decide the nature of the network, some basic questions need to be addressed :

- What is the expected volume of information that will be transferred on the network?
- Which information users need what information, how often, and why?
- What infrastructure, architecture, and protocol best match an information user's needs?
- What infrastructure, architecture, and protocol are the most efficient to implement?

- Is information "push" or "pull" more appropriate for a particular information item or user?
- Is it better to send the processed signal over the network as received or is it better to transform it into a different format?
- What are the functional needs for data archiving and storage?
- Should a distributed information network be used instead of a major, centralized database for storage and retrieval of archived information?
- What are data integrity and data security issues; how should they be addressed?

For Coast Guard purposes, operational requirements and priorities will define the local-to-nationwide system for receiving, processing, distributing, and assessing AIS information. The requirements should lead to the philosophy of the data flow and design of the architecture, and information transfer protocols. One way to look at requirements is by a review of operational needs. This approach starts where the information is collected, a local unit's AIS receiver, and then proceeds up through command and control layers.

Depending on the geographic area, the "local unit" (that receives and processes the AIS signal) can vary in size, staffing, and mission from a small Coast Guard boat station to a large Vessel Traffic Service (VTS). Although the boat station may need to act on the information, it is likely the next higher operational level has resources to monitor AIS on a continuous basis, and maintain an AIS information database or archive. For this reason the live information should be automatically "pushed to" the next-higher level for 24-hour monitoring and database upkeep.

The VTS site that directly receives and processes AIS signals is different. The VTS is staffed for 24-hour monitoring, but other Coast Guard operating units within the Vessel Traffic Service area most likely have the resources to respond in situations that require a physical presence. In this case, the operating units should see the common, AIS-derived, information picture.

As information flow develops, there may be a desire to have regional or national surveillance centers that process AIS-derived information. Large gains in statistical analysis, database maintenance, and possibly data mining might be realized if information sets (or subsets) were automatically retained at a centralized processing center.

The network consists of two major information transfer protocols. The first is the continuous flow of AIS information from base stations to hub server processes. This is the information "push" portion of the network. The second is conditional flow of AIS information that is provided on demand by these server processes. This is the information "pull" portion. These server processes can provide "value added" features such as elimination of redundant data and filtering. Though it will be within the capability of a remote AIS base station to "relay" signals,[33] where possible, the preferred method to exchange information with a base station is through a shore network not through the VDL.

As seen in the San Francisco Bay Demonstration Project, over 20 non-Coast Guard interests use live AIS-like information available through an Internet server.[34] Though this client-server

[33] Note: The use of a shore-based transmission or relay of AIS information will not be extensively covered in this paper. An example of a shore-based AIS network, including discussion of the VHF data link and messaging is found at the St. Lawrence Seaway website.
[34] Edwards and Pietraszewski.

system has received acclaim, future information availability may rely less on a client-server relationship and more on a peer-to-peer architecture. Research is being conducted on this issue. It focuses on developing an effective and efficient infrastructure for maritime information exchange within the Coast Guard and among the MTS.[35] This effort, called the "Waterway Information Network"(WIN) will develop a demonstration model of a network, based on distributed content management. In addition to protocols and information transfer issues, WIN will investigate the means for maintaining the integrity of navigation information during transport and filtering.

AIS - Where Are We Going?

AIS has potential as a useful tool for many purposes. In the Coast Guard, most AIS-development emphasis has involved vessel traffic management and technical aspects of standards development. Since September 11, littoral state monitoring (maritime domain awareness) has received greater focus. However, the primary AIS purpose, collision avoidance, still needs attention.

Vessel to Vessel – Collision Avoidance

Anticipating implementation schedule compression and U.S. carriage requirements, there will be a large number of AIS equipped vessels transiting ports and waterways in 2 years. Proposed legislation includes all vessels covered by the Bridge-to-Bridge Radiotelephone Act, some small passenger vessels, and towing vessels.[36,37] Since the Bridge-to-Bridge Radiotelephone Act includes every power-driven vessel of twenty meters or over in length,[38] the number and type of AIS equipped vessels will be substantial, possibly in excess of 18,000 vessels in the U.S.

AIS use in collision avoidance could lead to revision of the International Regulations for the Prevention of Collision at Sea. It may affect the "Steering and Sailing Rules" - lookout, action to avoid collision, and conduct of vessels in restricted visibility.[39] IALA's discussion on the role of AIS in collision avoidance[40] and the IMO AIS Guidelines[41] form a base to begin an evaluation of AIS collision warning and avoidance techniques. U.S. involvement and leadership might begin with efforts by the Navigation Safety Advisory Council (NAVSAC), Coast Guard and Navy vessel operations and training staffs, and the Maritime Academies. Incorporating AIS information in simulator training should be undertaken.

In their AIS Guidelines, IMO highlights inherent limitations of AIS. In addition, they warn that the AIS picture may not be the complete picture, and the Guidelines note "the accuracy of AIS information received is only as good as the accuracy of the AIS information transmitted."[42] There are also issues surrounding the timeliness of data. Very accurate but delayed data can

[35] Spalding, J. W., Shea, K. M., Lewandowski, M. J. "Intelligent Waterway System and the Waterway Information Network" Presented at the Institute of Navigation National Technical Meeting, San Diego. January 29, 2002.
[36] 107th Congress 2nd Session. H.R. 3983, Maritime Transportation Antiterrorism Act of 2002. Congressional Record. Washington, DC. March 18, 2002.
[37] United States Senate. S. 2329, Ship, Seafarer, and Container Security Act. Congressional Record. Washington, DC. April 25, 2002.
[38] Public Law 92-63, Section 7. Bridge to Bridge Radiotelephone Act. Washington, DC. August 4, 1971.
[39] IMO. 72 COLREGS.
[40] IALA, Guidelines on Universal AIS. pp 54-61
[41] IMO. Guidelines for the Onboard Operational use of Shipborne AIS pp. 6-9
[42] Ibid. p. 9.

create problems. Short term motion of the ship's GNSS antenna may not convey the true intent of a ship maneuver. An "instantaneous" AIS signal may not give as timely a picture as can be determined by seaman's eye. This is not to detract from the potential of AIS as a collision avoidance tool, but to restate that it is one of "all available means" to prevent collision.

There are other aspects of AIS implementation/installation, especially aboard small vessels:

- How and where AIS information will be displayed,
- Where will antennas and the AIS unit be installed,
- What level of operator training and guidance is appropriate, and
- What is an acceptable cost for the equipment, for those small vessels covered under proposed national regulations?

Naturally, after Class A AIS devices become mass-produced, the cost will be expected to decrease (as did GPS receivers). Initial Class A equipment is priced around $10,000.

Shore-Based AIS

As mobile AIS devices begin to proliferate, a tremendous amount of information will be available to anyone with a receiver. Though questions were raised earlier with regard to the nature of the network, additional, and possibly more fundamental, issues include:

- Are there legal limitations on storing and redistributing mobile AIS station reports?
- What is the liability of distributing incorrect information?
- Is recovery of operating costs possible?

These issues are directly tied to receiving AIS information and what is done with it.

USCG program and support managers must examine their relationship to the AIS with respect to existing or planned systems, i.e. Ports and Waterways Safety System (PAWSS) and National Distress Response System (NDRS). Initial emphasis will be on reception for mobile AIS reports for waterways management and maritime domain awareness. However, as AIS use expands, the need for safety related broadcasts will grow in importance. It is easy to consider installing AIS base-stations at high-level NDRS sites. Informal reports indicate that signal interference on the VHF-FM voice channels exists when an AIS base station, co-located with a VHF-FM voice receiver antenna, broadcasts. If co-location is considered, the amount and severity of AIS transmitting interference to voice channels must be evaluated to determine if interference is unacceptable. Obviously, this also depends on the amount of expected AIS transmission from the particular base station, and should be factored into any nationwide AIS implementation plan. The St. Lawrence Seaway AIS is designed to frequently transmit, and their AIS base-stations are co-located with their existing VHF-FM voice towers. Their experiences may provide a practical understanding of the interference issue.[43]

Aid to Navigation AIS

The potential benefits from AIS-equipped aids to navigation are obvious. In addition to "remote" AIS reception and relay (either via network or by the device acting as a repeater), its own broadcasting of performance monitoring information and actual position could alleviate numerous vessel sorties used to check operation and position. As AIS device cost constraints

[43] AIS Project. Great Lakes St. Lawrence Seaway System

could affect the number of aids to navigation fitted, one approach might be to outfit only major "seacoast" aids to navigation. Before this occurs, survivability testing of the AIS device is required to see if a device survives the constant exposure and extreme motions experienced by a buoy.

While IALA Guidelines consider AIS a possible complement to radar transponder beacons (RACONs),[44] if AIS devices are found to be able to operate effectively on floating aids to navigation, cost benefit analysis could show that elimination of RACONs on aids to navigation is feasible. While offshore structures, such as oil platforms, are not categorically defined as "aids to navigation,"[45] AIS use for identification is also worthy of consideration – Gulf of Mexico safety fairways. Chapter 14 of the IALA Guidelines further describes an ATON AIS station and messaging in detail.[46]

Conclusion

During the next two years, new regulations will require a number of vessels to begin carrying Class A AIS equipment. If the IMO implementation schedule is compressed and proposed domestic legislation is passed, a significant number of vessels in or near the United States will soon carry AIS units. A detailed and thorough description of information needs, based on sound, information-user mission analysis is paramount to implementing a comprehensive information system and network infrastructure. All MTS stakeholders can benefit from an AIS high-level system that takes advantage of the information provided by this technology. AIS will be major element of an Intelligent Waterways System.

[44] IALA. P 127
[45] Ibid.
[46] IALA, p 127-133.